Promoting Customer Satisfactions by Applying Six Sigma: An Example from the Automobile Industry

S. C. CHEN, DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT, TAICHUNG, TAIWAN, R.O.C.
K. S. CHEN, DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT, TAICHUNG, TAIWAN, R.O.C.
T. C. HSIA, DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT, CHIENKUO TECHNOLOGY UNIVERSITY, CHANGHUA, TAIWAN, R.O.C.

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Presently the automobile industry in Taiwan is in the product maturity stage. The market is saturated while the market scale has remained unchanged. A set of effective quality control performance and improvement models needs to be established. By initiating a mechanism of low cost and high processing speeds, an improved competitiveness will develop in this highly competitive, highly demanding, and constantly changing environment. This, in turn, will create a product of high customer satisfaction, which is needed for the industry to survive. The major focus of previous papers has been on the evaluation and improvement of manufacturer's quality with little or no emphasis on customer-related qualities, such as design, manufacturing, service, and customer satisfaction.

Following the design, measure, analyze, improve, and control (DMAIC) model of Six Sigma (George 2002) and using the automobile industry as a case study, the authors "measure" the performance of the customer's requirement. They do this by creating a questionnaire and "analyzing" the performance of the product quality mechanism. This is then transferred to a related product specification. Next, they use key elements found in the quality process, performed by related sectors, as a countermeasure for planning and "improvement." Finally, they equip management with a complete model of evaluation and improvement to help define, measure, analyze, improve, and control the product quality mechanism quickly and effectively. Thus, a better customer satisfaction and business profit can be achieved by creating a perfect product quality and service value through a timely and effective promotion of product design, manufacturing, and service quality.

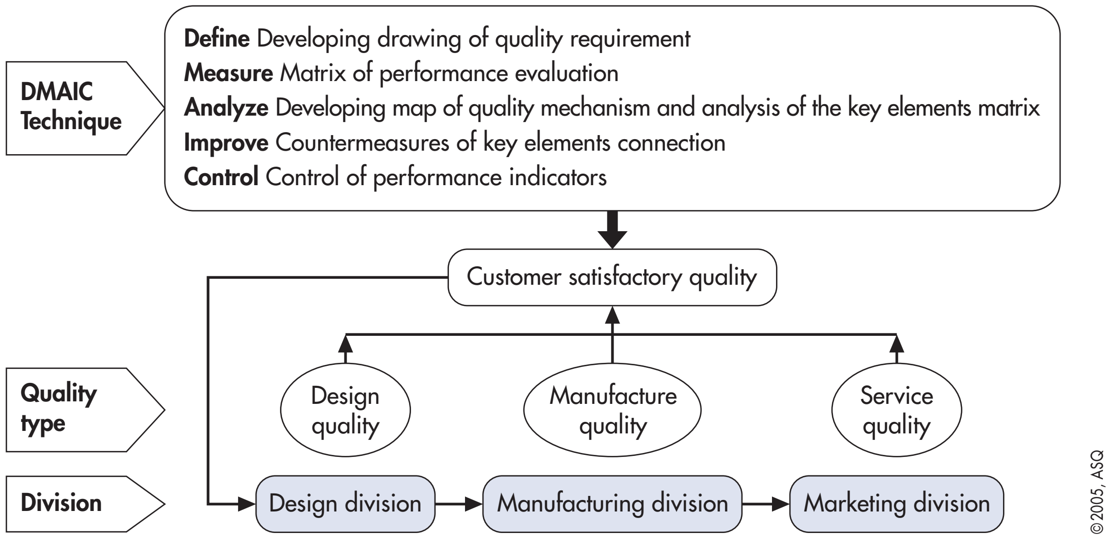
Key words: cause analysis chart, matrix of performance evaluation, process capability index, quality function development, Six Sigma

INTRODUCTION

Having reached its product maturity stage, the automobile industry in Taiwan is now experiencing a renewed research and development effort, which is promoting intense competition. Unable to grow the market, the industry's efforts have produced a major improvement in product function and quality and a gradual reduction of production costs. Product quality, for example, has gone beyond its initial goals in the area of basic requirements and has met its function requirements of comfort, cleanliness, and quietness. Unless an effective management model of performance characteristics is created to produce high quality and high value, the Taiwan automotive industry will be unable to survive in the highly competitive and changing business environment it is now in. The industry will also need a service of high customer satisfaction. This will be achieved via a low cost, fast process function.

Upon establishing a quality and performance management model, a concise principle must be adopted to construct the functions of design, manufacturing, marketing, and customer relations. The goal of high product and service quality can be achieved by controlling design, manufacturing, and marketing, as well as the key influential elements in the various departments involved. One must also eliminate the quality vacancies between each department. To achieve these goals one must first analyze the operational process of each department in the business. The design department must be given information on customer satisfaction in order to create a high-quality

Figure 1 Industry quality process influential factors chart.



design that will meet customer requirements. The manufacturing department must then produce the desired products based on the design unit's ideas. Then the marketing department must take the final product and target the desired customers. By following this process, it is logical to assume that high customer satisfaction and low dissatisfaction will result. This is achieved only when the various sectors involved in the process put forth a high level of excellence. A model based on this concept is shown in Figure 1.

It is necessary for the industry to construct a practical application to solve the current problem and to improve its present condition by improving customer satisfaction and lowering customer dissatisfaction. Six Sigma is one of the best methods to do this. According to Pande et al. (2000), excellent results have been achieved by many world-renowned businesses introducing the Six Sigma management improvement method, including Motorola, General Electric (GE), and Sony. For example, GE increased its an annual profit by $750 million in 1998 due to its implementation of Six Sigma. In 2000, Motorola, using Six Sigma, brought a 21 percent annual rise to its stock price. By following the define, measure, analyze, improve, and control (DMAIC) model of Six Sigma (George 2002) and Pyzdek's model (2001), the authors identify the key process elements found between the various sectors in industry. A perfect customer satisfaction can be achieved by promoting high-quality design, manufacturing, and service.

Previous papers have focused mainly on the evaluation and improvement of the manufacturer's quality, while the customer satisfaction related factors of design quality, manufacturing quality, and service quality have been overlooked. These three qualities are in fact mutually dependent on one another. (Note that it is not implied that the automotive industry has overlooked these qualities, only papers on this subject.)

Using the Taiwan automobile industry as an example, this study aims to explain how to define the problems to be improved and analyze the causes of these problems using customer opinions and by applying Six Sigma to a performance matrix. The authors use a countermeasure, which points out the causes and helps to make improvements in order to achieve customer satisfaction.

The eight dimensions of product quality identified by Garvin (1987) include: 1) performance; 2) reliability; 3) durability; 4) serviceability; 5) aesthetics; 6) features; 7) perceived quality; and 8) conformance to the standard.

These quality dimensions are expanded from the characteristics of a product using the supply-push model. But technologies' point of view is that the

Table 1 Description of quality mechanisms.

Quality type	Insufficient to cause dissatisfaction	Sufficient to improve satisfaction	Quality mechanisms
Nondifferential quality	Somewhat yes	No	If an improvement of one portion of the mechanism weakens the effectiveness of other parts of the mechanism in the same product.
Charm quality –Luxury quality	No	Yes	If the essential factor is sufficient, the customer will be satisfied. If the essential factor is insufficient it won't influence the customer's satisfaction.
Linear quality –Expected quality	Somewhat yes	Somewhat yes	If the essential factor is insufficient, it won't influence the customer's satisfaction, while the essential factor sufficient will get satisfied.
Should-be quality, basic quality	Yes	No	If the essential factor is sufficient, it won't influence the customer's satisfaction, while the essential factor insufficient will become dissatisfied.
Ineffective quality	No	No	If the essential factor is sufficient or insufficient, it won't influence the customer's satisfaction.

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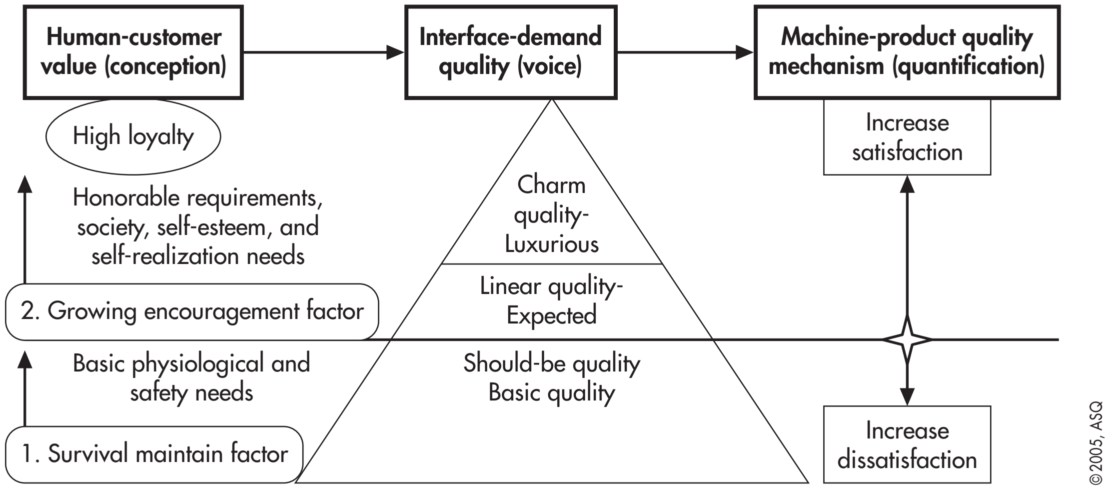
product is already out there and just needs to be brought forward into the marketplace. So the quality characteristics of the product must be determined by what the public requires. Kano (1984, however, proposes five quality categories, which come from the public's requirements and are based on a requirement-pull model. The five quality categories are established from customer satisfaction and the level of quality mechanisms. They are: 1) nondifferential quality; 2) charm quality (luxurious quality); 3) linear quality (expected quality); 4) should-be quality (basic quality); and 5) ineffective quality (see Table 1). Thus, the authors integrated Kano's five quality categories (Kano 1984), Maslow's hierarchy of human requirements (Maslow 1954), and Herzberg's dual factors theory (Herzberg, Mausner, and Snyderman 1959) with the concept of the human-machine system to construct a quality questionnaire.

Based on the KJ method presented by Kawakita Jiro (1986), questionnaire items were defined. Upon completion, a performance matrix evaluation chart was constructed based on the importance and satisfaction of the questionnaire items. Using this performance matrix a measurement of the performance quality mechanism was done on each item. The focus was on two key items: 1) those with the highest importance but with the lowest satisfaction, and 2) those with the lowest importance but with the highest satisfaction. By analyzing the quality mechanism developing chart and key factor matrix analysis chart, the authors can transfer these two key items into influential factors that affect the design, manufacturing, and service sectors. By being unfamiliar with the key product mechanisms or being unaware of engineering specifications, the design sector will fail to grasp the key customer requirements. This failure may also be a result of the manufacturing sector's inability to upgrade a key product mechanism characteristic through an effective definition of the important key processes.

Another factor may arise from the marketing sector for being unable to effectively evaluate the key product mechanism or their inability to make the connection between customer satisfaction and dissatisfaction and thus learn the key customer requirements. Using these influential factors that require improvement, a countermeasure connection chart can be developed from which key elements from each sector may be found and enhanced. A related inclusive policy can then be planned by pointing out the limitations encountered during the process. Finally, in the control portion of the DMAIC, countermeasures must be introduced using performance indicators to achieve and maintain the expected results.

Through the DMAIC the company can make an effective and fast definition of the customer's requirements and take quality measurements. They can then analyze the performance of the process management

Figure 2 Thinking process of the quality mechanism questionnaire.



to identify the key influential factors that require improvement. In the end they will reach the required standards in each sector. The quality of product design, manufacturing, and service are being promoted and will reach a level of perfect satisfaction in regard to product quality.

DEFINE THE QUALITY MECHANISMS OF THE PRODUCT

It is recommended by Pande et al. (2000) that when defining a problem, one should first look at the problem from the customer's point of view. Only after making improvements can the service one provides meet the customer's requirements and further promote the customer's satisfaction and loyalty.

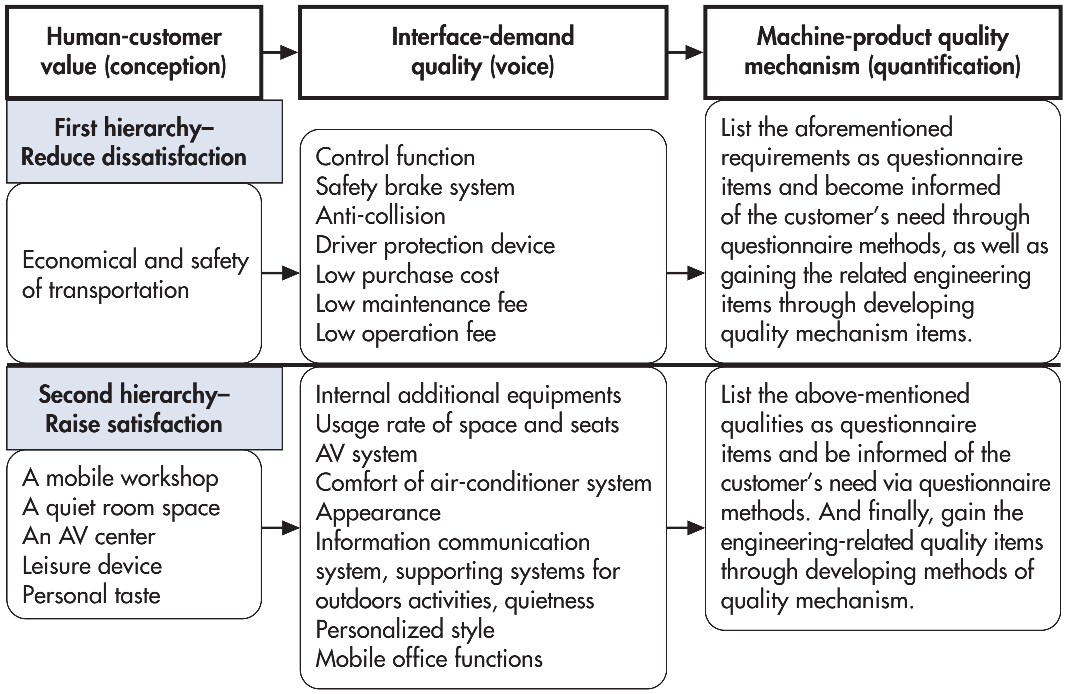
Before defining the key quality mechanisms of the product, one must first find and target the market segmentations. The next step is to evaluate the potential of the target market to decide whether it is worth developing, and, finally, define the static and dynamic mechanisms of each market sector. Therefore, according to the five quality mechanisms proposed by Kano (1984), to define customer satisfaction and the dissatisfaction questionnaire items the authors raise the effectiveness of the questionnaire.

The product quality mechanism derives its source from human requirements. The authors integrate Kano's five quality mechanisms, Maslow's (1954) hierarchy of human requirements, and Herzberg's (Herzberg, Mausner, and Snyderman 1959) theory of dual factors to construct a quality mechanism questionnaire items thinking procedure chart based on the human-machine system concept, as shown in Figure 2. To examine the questionnaire items shown in Figure 2, one must start by developing a hierarchy of physiological and safety requirements (human-customer value) to define the conceptual requirements and to find out the primary should-be quality of the product (interface-demand quality) and further define its colloquial requirements. Then one can begin to find related product quality mechanisms and define its quality of quantified requirement by developing should-be quality mechanisms.

With sufficient elements of product quality in the first hierarchy, no customer dissatisfaction will result. Customer satisfaction, however, will not be affected by any insufficient elements that would encourage a growing encouragement of satisfaction. The situation described previously is regarded as providing survival maintaining factors. By just providing the survival maintaining factors the customer may never be satisfied.

When the first hierarchy has been completed the second hierarchy can be addressed. The first step is the human-customer value, which involves society,

Figure 3 Developing drawing of quality requirement.



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self-esteem, and self-realization. The second step is the interface-demand quality, which defines the conceptual requirements and identifies the linear qualities, charm qualities, and nondifferential qualities. The third step, the machine-product quality, can be developed to define the quantified requirement quality. If there are insufficient factors in the product quality mechanism of the second hierarchy, the customer will not be dissatisfied; if there are sufficient elements, customer satisfaction will be promoted, and thus there will be an incentive for growth.

After establishing the related thinking model and procedure, the last step is to reference the KJ method of Jiro (1986) to define the questionnaire-related quality mechanism items. For example, if one looks at the basic physiological and safety requirements of the first hierarchy, as shown in Figure 2, then a car is regarded as a transportation means. One will then learn the major should-be mechanisms (interface-demand quality) of the car, for example, control function, a highly reliable brake system, an anticollision and driver protection device, a low purchase cost, a low maintenance fee, a low operation fee, and so on. By using the questionnaire method, listing the aforementioned requirements as questionnaire items, as well as gathering the related engineering information through developing quality mechanism items, one will become aware of the customer's expectations (see Table 1).

In terms of the second hierarchy, the car should be regarded as a mobile office equipped with the same functions as a typical office, such as being quiet and comfortable, having an audio-visual (AV) center, expressing personal style, and so on. One can then develop these customer values and find out the linear qualities, charm qualities, and nondifferential qualities (interface-demand quality), such as additional internal equipment, use of space and seats, AV system, environmental comfort, appearance, information and communication systems, supporting systems for outdoor activities, quietness, and meeting and office requirements. The authors list these qualities as questionnaire items so as to become aware of the customers' requirements. The engineering-related quality items, using the developing methods of the quality mechanism, can then be acquired (see Figure 3).

THE PERFORMANCE EVALUATION MATRIX AND INNER VOICE OF CUSTOMERS

The topmost goal of product quality is to gain customer satisfaction. High product quality will mean little or nothing if the customer is not satisfied. The viewpoint of the customer needs to be used to develop the questionnaire items, as shown in Figure 2. Then the performance characteristics of quality importance and satisfaction can be defined according to the idea developed by Huang, Huang, and Chen (2003).

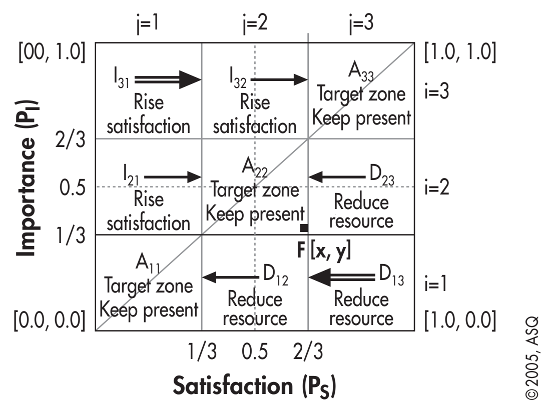
$$P_I = \frac{\mu_I - min}{R}, \; P_S = \frac{\mu_S - min}{R} \qquad (1)$$

Among the random variables, P_I represents the importance index value, P_S represents the satisfactory index value, μ_I represents the mean value of importance, μ_S represents the mean value of satisfaction, and K represents the maximum number of choices. The minimum value of K, which equals 1, is represented as min. R (the full range) = K−1. As the index value gets lower, the importance or satisfaction of the product goes down. The value of these two indexes will fall between and include 0 and 1.

For example, on a scale of 5 (K = 5), the full range is R = K−1 = 4. An importance index value of 1 represents the lowest importance, 3 represents the medium importance, and 5 represents the highest importance index. When the average mean value of importance (μ_I) is higher than 3, the index value will be larger than 0.5. This indicates a positive total average importance. On the other hand, when the average mean value of importance is lower than 3, the index value will be smaller than 0.5. This indicates a negative total average importance. The index value will allow one to decide whether the customer evaluation of the quality mechanism is a positive or a negative importance. The same example applies to calculating satisfaction.

The authors used the modified performance evaluation matrix of Huang, Huang, and Chen (2003) to measure the product mechanism performance (see Figure 4). This modified performance evaluation matrix expresses both importance and satisfaction of

Figure 4 Matrix of performance evaluation.



the product mechanism items. The x-axis on the matrix indicates satisfaction, while the y-axis indicates importance.

Both the x and y axes can be divided into three separate ranges, 0.0 to 1/3, 1/3 to 2/3, and 2/3 to 1/0. A range of 0.0 to 1/3 indicates low satisfaction, 1/3 to 2/3 indicates medium satisfaction, while 2/3 to 1.0 indicates high satisfaction. This same scale is also used to indicate importance.

When indexes (P_S, P_I) = [0.0, 0.0], a low importance is expressed. When indexes (P_S, P_I) = [1.0, 1.0], it means a high importance, and when indexes (P_S, P_I) fall between the scales of [1/3, 1/3] and [2/3, 2/3], then a medium importance and satisfaction are expressed. The dotted line (P_S = 0.5) on the y-axis means medium importance, the zone above the dotted line means a higher average importance than unimportant. The dotted line (P_S = 0.5) on the x-axis means medium satisfaction. The right-hand zone means a higher average satisfaction than dissatisfaction. If one uses A_{ij} (proper target zone), I_{ij} (increased resource zone) and D_{ij} (decreased resource zone) (i, j = 1, 2, 3) to indicate the nine performance zones, then the three performance zones A_{11}, A_{22}, and A_{33} mean a similar satisfaction and importance of the promoting items, here referred to as "proper performance zone."

It should be the primary goal of any business to achieve the highest customer satisfaction. Cost must be taken into consideration in searching for the key product mechanism items and in controlling of proper quality performance standard. Guided by the principle of "proper quality performance standard," the industry not only satisfies the customer's requirement, but also maintains a fixed quality performance standard while lowering product development costs. The industry must set its priorities while promoting product development strategies. It is necessary to define the "target zones" of the product development performance matrix so they fall in the "proper performance zones." In other words, the target zone should fall in zones A_{11}, A_{22}, and A_{33}, when the importance equals the satisfaction ($i=j$). In zones I_{21}, I_{31}, and I_{32} the satisfaction is less than the importance ($i < j$), and when the satisfaction is higher than the importance ($i > j$), the target zone falls in zones D_{12}, D_{13}, and D_{23}, as shown in the performance matrix model presented by Huang, Huang, and Chen (2003). The goal is for the coordinate points to fall on or near the scale line through proper performance zones.

Table 2 Performance of product quality mechanism.

Product quality mechanisms	μ_I	μ_A	P_I	P_A	e_{ij}
A. Reduce Dissatisfaction					
1. Brake system	4.52	4.33	0.88	0.83	0.002256
2. Anti-collision	4.25	4.21	0.81	0.80	0.000100
3. Driver protection devices	4.5	3.86	0.88	0.72	0.025600
4. Low purchase cost	3.16	3.11	0.54	0.53	0.000156
5. Low maintenance fee	3.86	3.33	0.72	0.59	0.017556
6. Low operation fee low fuel consumer	3.96	3.57	0.74	0.64	0.009506
B. Increase Satisfaction					
1. Internal additional equipment	4.23	3.56	0.81	0.64	0.028056
2. Use of space and seats	3.89	3.31	0.72	0.58	0.021025
3. AV system	3.62	2.03	0.66	0.26	0.158006
4. Environmental comfort	4.21	3.97	0.80	0.74	0.003600
5. Appearance	3.65	3.09	0.66	0.52	0.019600
6. Information and communication systems	4.62	3.08	0.91	0.52	0.148225
7. Supporting systems for outdoor activities	3.02	3.09	0.51	0.52	-0.00031
8. Quietness	4.52	2.07	0.88	0.27	0.375156
9. Personalized style	2.86	2.91	0.47	0.48	-0.00016
10. Meeting and office requirements	4.11	2.46	0.78	0.37	0.170156

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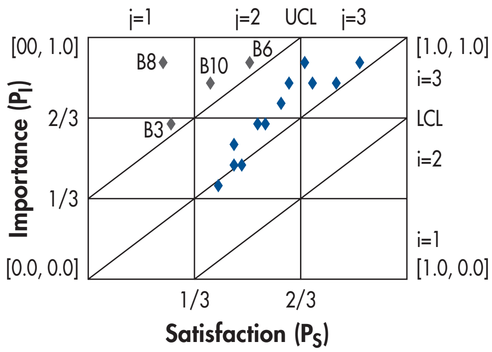
Due to the failure of the aforementioned coordinate points to provide an objective judgment as to which product requirement should be improved, the authors present a triangle zone formed by diagonal lines to set up a performance evaluation model. They call these target lines. The total zone of the matrix is $1\times1=1$. The zone (ρ_T) of the isosceles triangles above and below the diagonal lines is 0.5. Assume the coordinate points (P_S, P_I) fall on F (x, y), the zone of triangles surrounded by the diagonal lines is $\rho_{ij}=((x-y)^2)/2$.

The authors used the ρ_T value of the isosceles triangle as the denominator and the ρ_{ij} value of the triangles formed by coordinate points and diagonal lines as the numerator to formulate a ratio value as performance indexes. The equation is as follows: rewrite the stated equation as $e_{ij}=(x_i-y_j)\times|x_i-y_j|$ in order to tell whether the performance falls within the increased resource zone or decreased resource zone. When performance value e_{ij} is positive, then resource must be increased to promote satisfaction to a proper zone; when performance value e_{ij} is negative, then resource must be decreased to save investing cost.

Finally, the authors explored the "importance of the product quality mechanism" and "satisfaction of the product quality mechanism." Using the questionnaire designed earlier, they targeted 100 automobile customers. Of the 100 questionnaires that were sent out, they received 51 responses, of which 45 had useful data. A credibility analysis was performed using these data. The internal credibility was listed as the most important item within the multiple item scales. When the authors refer to the internal credibility they mean

Figure 5 Matrix of quality performance evaluation.



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whether each scale measures the single concept and represents a consistence within the combination of items at the same time as proposed by Gay and Airasian (1992).

A popular way to check the reliability of the data is to use Cronbach's alpha, which the authors have adopted here. According to Gay and Airasian (1992), credibility over a Cronbach's alpha of 0.90 is excellent, while a Cronbach's alpha of 0.80 or under represents a mere acceptable credibility. DeVellis (1991) and Nunnally (1978) regarded a Cronbach's alpha of 0.7 and up to be a minimum acceptable credibility accounting. After completing of the analysis, they gained a Cronbach's alpha of 0.914. While on individual credibility, the authors gained a 0.8678 of importance credibility, and a 0.9015 of satisfaction credibility. According to the standard set by scholars, they got a fairly high Cronbach's alpha, which shows the results to be stable and consistent. The authors then followed by filling in the importance average mean μ_I, and the satisfactory average mean μ_S on Table 2. The index value of importance, P_I and index value of satisfactory P_S, were then defined based on Formula 1. The quality performance matrix evaluation chart was drawn, as shown in Figure 5. The corresponding e_{ij} value of coordinate points and diagonal lines was calculated according to Formula 1.

P_I represents the importance index value, P_S represents the satisfactory index value, μ_I represents the mean value of importance, μ_S represents the mean value of satisfaction.

Looking at Table 2, one can see that the performance value of the following four quality mechanisms score too high: AV system (B3), information and

Table 3 Developing map of quality mechanisms.

Increase resource for rise satisfaction		Quality specifications								
Product quality mechanism Compose performances e_{ij}		1. Soundproofing ability of windows	2. Soundproof effect of engine room	3. The chassis noise value	4. The engine noise value	5. Wireless Internet communication	6. The effects of air conditioner	7. Automobile-room illumination	8. The effects of three-D sound	9. Power supply system
Rise satisfaction										
B3. AV system	0.158006	1.0	1.0	1.0	1.0	1.5	0.0	0.5	2.5	1.0
B6. Information and communication	0.148225	0.5	0.5	0.5	0.5	2.5	0.0	0.5	1.0	2.0
B8. Better quietness	0.375156	2.0	2.0	2.0	2.0	0	0.5	0.0	0.0	0.0
B10. Moveable office	0.170156	1.0	1.0	1.0	1.0	2.0	2.0	2.0	0.5	2.0
Total		1.153	1.153	1.153	1.153	0.9479	0.528	0.493	0.628	0.795
Rank		1	1	1	1	2	6	5	4	3

Note 1: Absolute relational (2.5), E Greatly relational (2.0), I High relational (1.5), O common relational (1.0), U Slightly relational (0.5), X Irrelevant (0)

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Table 4 Development of the quality specifications.

The whole quality		Satisfied quality								
IPO process quality		Design quality (input)			Manufacturing quality (process)			Maintain service quality (output)		
Quality specifications Strategy performance		4M	Environment	Design investigate	4M	Environment	Process inspection	4M	Environment	Customer complain
Quality specifications										
1. Passenger compartment soundproofing	1.1526	5.0	1.0	4.0	5.0	2.0	1.0	1.0	3.0	3.0
2. Engine room soundproofing	1.1526	4.0	1.0	3.0	4.0	1.0	1.0	2.0	1.0	3.0
3. Chassis noise	1.1526	5.0	1.0	4.0	5.0	1.0	1.0	3.0	1.0	3.0
4. Engine noise	1.1526	5.0	1.0	5.0	5.0	1.0	2.0	4.0	1.0	3.0
Total		21.90	4.61	18.44	21.9	5.76	5.76	11.53	6.916	13.83
Rank		1	7	2	1	6	6	4	5	3

Note 1: 4M, Man, Material, Machine, Method
Note 2: Absolute relational (5.0), E Greatly relational (4.0), I High relational (3.0), O Common relational (2.0), U Slightly relational (1.0), X Irrelevant (0.0)

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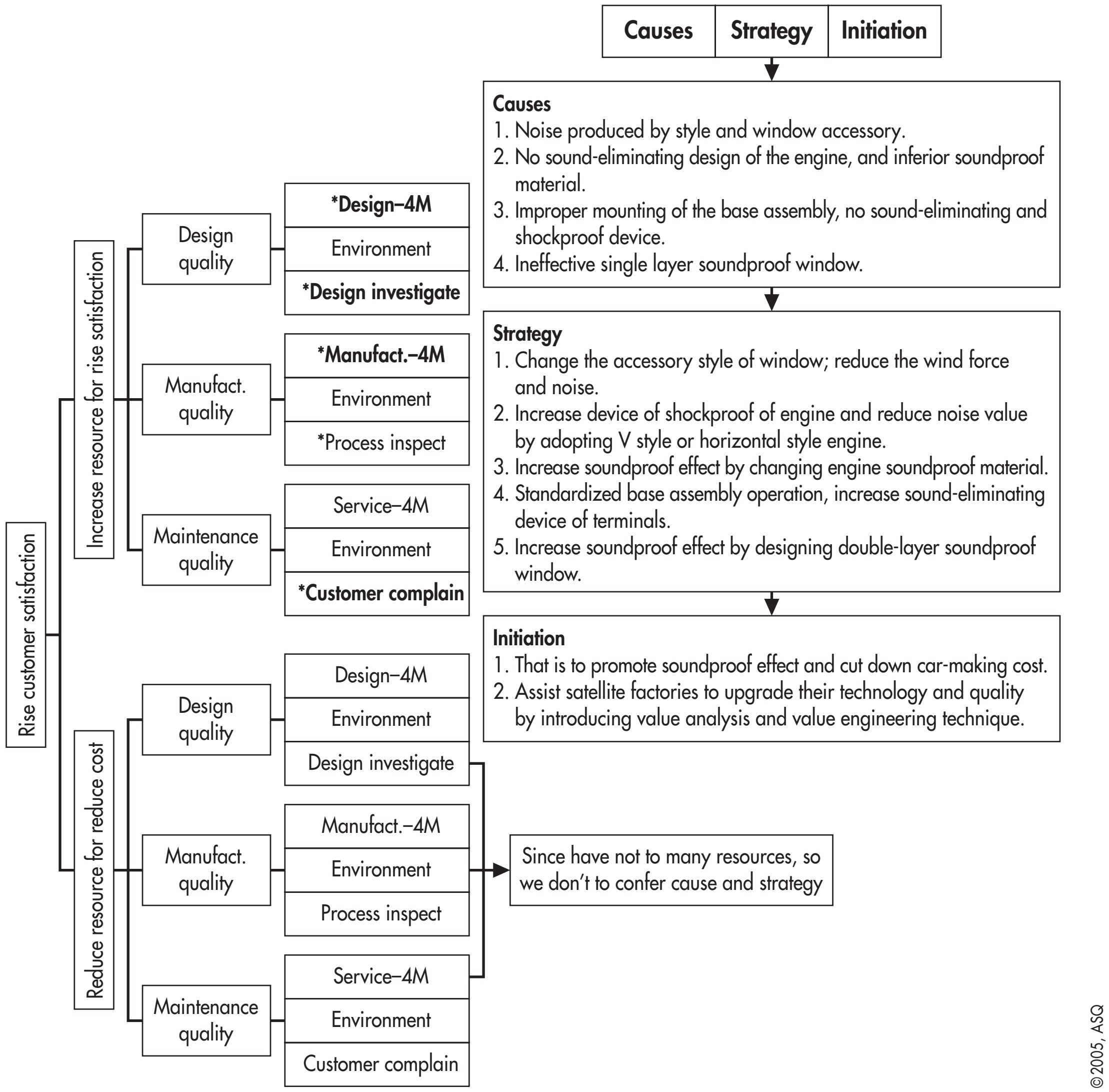
communication system (B6), quietness (B8), and meeting and office requirements (B10). They also are seen in Figure 5 as being positive. This means the importance is higher than the satisfaction, and additional resources must be invested to promote satisfaction.

ANALYSIS AND IMPROVEMENT OF THE QUALITY MECHANISM

It is these four quality mechanisms—AV system, information and communication system, quietness, and meeting and office requirements—that are the focus of the analysis. Following the first and second hierarchy in Figure 3, and taking the advice of engineering experts, nine quality specifications were established. Then, using the e_{ij} value and the engineering expert's weighted value, the authors calculated the totals for each quality specification. These totals were then ranked. Four key quality specifications ranked as number one, having a total value of 1.153. These quality specifications require the most attention. They are: soundproofing ability of the passenger compartment, increase the soundproofing of the passenger compartment, soundproofing ability of the engine compartment, noise level of the chassis assembly, and the noise level of the engine, as shown in Table 3.

The key elements identified in Table 3 then need to be analyzed. Referring to Table 4, the satisfaction quality was divided into three areas based on the input, process, and output process (IPO). They are the design quality, manufacturing quality, and maintenance quality. Each of these qualities is subdivided into quality specifications strategy performances. Each quality has a value based on man, machine, material, and method (4M), and the environment. The design quality has a design evaluation value, manufacturing quality has a process evaluation value, and the maintenance quality has a customer complaints value. The quality specifications are multiplied by the engineering expert's weight values for the IPO process. As the authors did in Table 3, the totals are ranked.

Figure 6 Countermeasures of key elements connection.



Finally, improvement countermeasures were addressed by focusing on the top four key values of the satisfaction qualities, as identified in Table 4. These values are the 4M and design evaluation of the design quality, the manufacturing quality of the 4M in the manufacturing quality, and the customer complaints in the maintenance quality. Each key value must be addressed based on the causes for dissatisfaction. A strategy for improvement can then be devised, and an initiation of the improvements can be made. This is outlined in Figure 6.

The causes have four key items: the noise produced by the automobile style, the soundproofing design of the engine compartment, the soundproofing design of the chassis, and the soundproofing ability of the windows themselves.

There are five strategies for improvement: change the style of the automobile, reduce engine noise, increase the soundproofing ability of the engine compartment, increase the soundproofing ability of the chassis, and increase the soundproofing ability of the windows. A change in the style could mean changing

Figure 7 Taguchi quality loss function.

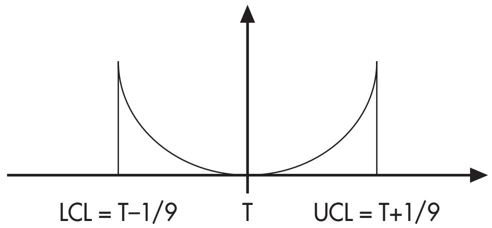
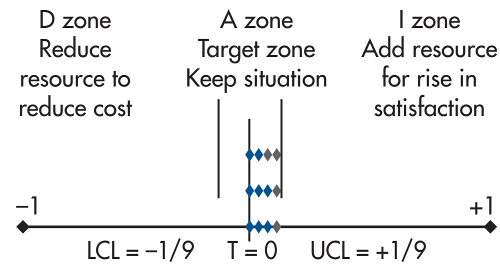


Figure 8 Control of performance indexes.



the design of the windows or changing the shape of the car to reduce wind resistance and thus reduce the noise. Engine noise could be reduced by changing the style of the engine. This could mean going to a V type or horizontal type of engine. It could also mean going to a different type of engine altogether, such as using an electric or hybrid engine. A change in the material used in the engine compartment could lead to an improvement in overall noise. Possibly by changing the style of the chassis or the method of engine/body mounting to the chassis would improve the sound quality. By converting all the windows to a double-layer design improvements could be made.

In the process of initiating the improvements several factors need to be addressed. The cost of the value engineering to make the necessary improvements should not substantially increase the cost of the automobile. The technology of the vendor's factories needs to be upgraded as well as an improvement in their quality by introducing value analysis.

CONTROL OF QUALITY MECHANISM AND STEPS OF EVALUATION

After implementing the stated improvements and countermeasures, one must ensure that the improvements and countermeasures reach and maintain the required level. The product mechanism must be monitored to ensure the best quality is maintained. Therefore, an effective controlling model must be established based on the up and down boundary lines of Shewhart's control chart (1939) and Taguchi's quality loss function (Taguchi, Elsayed, and Hsiang 1989). First, the authors set up a "zero" target value (T = 0) for the performance object. This means transferring the controlling lines of the quality performance matrix evaluation chart to upper and lower boundary lines of indexes on the controlling chart. The starting coordinate point [0, 1/3] of the upper control line (UCL) and the starting coordinate point [1/3, 0] of the lower control line (LCL) are established. After calculating the e_{ij} value, the value of the upper and lower control lines can be obtained using Equations 2 and 3 respectively. The value of 1/9 is obtained by using the upper and lower control lines in Figure 7.

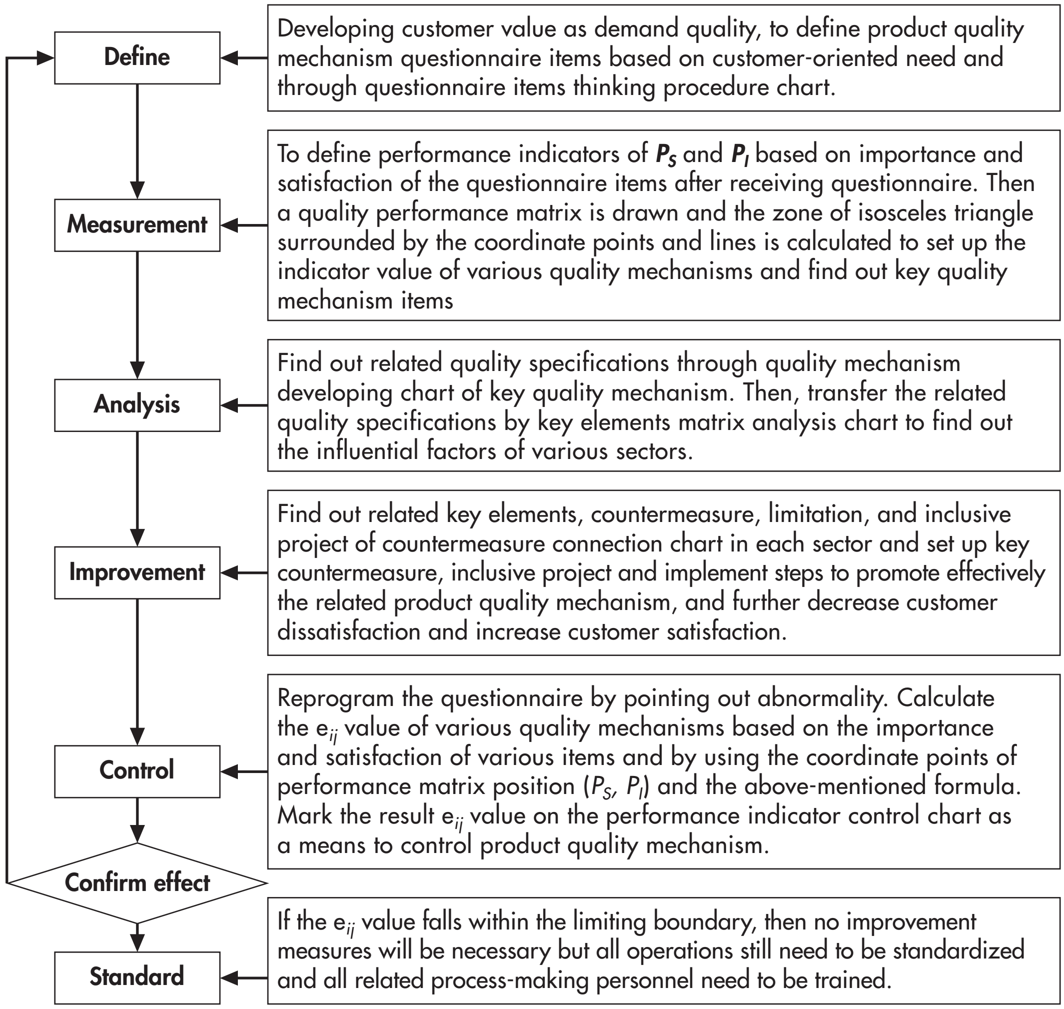
$$UCL = T + 1/9 \quad (2)$$

$$LCL = T - 1/9 \quad (3)$$

Similarly, as stated by Taguchi, Elsayed, and Hsiang (1989), the product quality mechanisms performance value should be as close to a T = 0 as possible. The greater the distance from T = 0 the greater the loss of quality.

Then the e_{ij} value from Table 2 is marked on the performance target-controlling chart (see Figure 8). When the e_{ij} value is greater than +1/9, it falls in the I zone, and the greater the e_{ij} value the higher the importance level is above the satisfaction level. This means more resources have to be invested to promote satisfaction. When the e_{ij} value is less than –1/9, it falls in the D zone, and the lower the e_{ij} value the lower the importance level is below the satisfaction level. Therefore, fewer resources need be invested. This will avoid wasting resources and will lower the cost. In addition, when the coordinate points of importance

Figure 9 Evaluation and steps of improvement of quality system.



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and satisfaction fall within the boundary lines of –1/9 and +1/9, the e_{ij} value falls near 0. The probability of falling into the proper target zone increases. The e_{ij} value may be defined as described in Figure 8 having a range between –1 to 1. The management will then be able to calculate the "e_{ij}" value of various quality mechanisms according to the coordinate points of the importance and satisfaction on the performance matrix position (P_S, P_I) and Formula 1.

Management can also draw a performance index controlling chart and use it as a means to control the product quality mechanism and take the next step to measure whether the aforementioned abnormal product quality mechanism falls within the upper and lower controlling boundaries. If not, improvement and initiation strategies have to be considered. Looking at the selected example, all of the current abnormal product quality mechanism items fall within the controlling boundary that indicates the expected improvement target has been reached. Final compilation of the evaluation is described in Figure 9.

CONCLUSION

This article integrated Kano's five quality mechanisms (1984), Maslow's hierarchy of human requirements (1954), and Herzberg's dual factors theory (Herzberg, Mausner, and Snyderman 1959), and combined this with the concept of the human-machine system and thus defined a thinking procedure map using quality mechanism questionnaire items. This customer requirement-pull model is different from the supply-push model traditionally used for the origin of product characteristics. This difference and thus advantage of the customer requirement-pull model is that the thinking process originates with the customer.

Using the Taiwan automobile industry as an example, the authors have presented how to improve the quality process using the Six Sigma method. In this case, they found the customer requirements and the key quality mechanisms and used these to identify the key quality specifications. The automobile industry may be able to improve its quality and business guidelines and further meet the satisfaction requirements of the customers in a timely and effective way. By using the DMAIC method a win-win situation is created.

As the saying goes, "Technology always comes from human requirements," so this article's proposed concept, thinking process, and improved model could be applied to other industries. Future studies in other area of industry will help to develop new and improved models.

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BIOGRAPHIES

Shui-Chuan Chen is an associate professor of industrial engineering and management at the National Chin-Yi Institute of Technology. He has a bachelor's degree in business administration from Dong-Hai, and master's and doctorate degrees in industrial engineering from Chiao Tung University. His research scope is quality management and performance management. He can be contacted by e-mail at scchen@chinyi.ncit.edu.tw .

Kun-Cheng Chen is a professor at the Institute of Production System Engineering and Management, National Chin-Yi Institute of Technology. He has a bachelor's degree in statistics from Dan-Jiang University, a master's degree in application mathematics from Cheng-Gong University, and a master's degree and a doctorate degree in industrial engineering from Chiao Tung University. His research scope is process capability index and quality of service.

Tai-Chang Hsia is an associate professor with the Department of Industrial Engineering and Management, Chienkuo Technology University, Changhua, Taiwan, R.O.C. He received his doctorate degree from National Chiao Tung University, Taiwan, R.O.C. His areas of research include manufacturing engineering, human factors engineering, and system safety.